

AD-A190 416

BODIES IN UNSTEADY FLOW(U) MASSACHUSETTS INST OF TECH  
CAMBRIDGE ACOUSTICS AND VIBRATION LAB P LEENEV  
30 DEC 87 87144-2

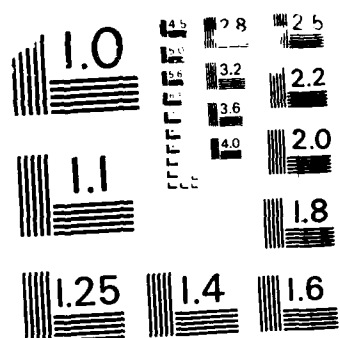
1/1

UNCLASSIFIED

F/G 20/4

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

SECURITY CLASSIFICATION OF THIS PAGE

## REPORT DOCUMENTATION PAGE

1a		1b RESTRICTIVE MARKINGS	
2a		3 DISTRIBUTION/AVAILABILITY OF REPORT	
2b		Unlimited	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)		5 MONITORING ORGANIZATION REPORT NUMBER(S)	
MIT Acoustics and Vibration Laboratory Report No. 87144-2			
6a NAME OF PERFORMING ORGANIZATION	6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION	
Massachusetts Institute of Technology		Office of Naval Research Code 1125A0	
6c. ADDRESS (City, State, and ZIP Code)		7b. ADDRESS (City, State, and ZIP Code)	
Cambridge, MA 02139		800 North Quincy St. Arlington, VA 22217	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
Office of Naval Research		-----	
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF FUNDING NUMBERS	
800 North Quincy St. Arlington, VA 22217		PROGRAM ELEMENT NO.	PROJECT NO.
		TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification)			
Bodies in Unsteady Flow, (U)			
12. PERSONAL AUTHOR(S)			
Patrick Leehey			
13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 1978 TO 1985	1987/12/30	4
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	Vortex shedding; shear stress, towed body, axisymmetric turbulent boundary layer	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
<p>Reports research accomplished on:</p> <p>Vortex shedding from a cylinder; Development of a floating element gauge for measuring shear stress; Axisymmetric towed hydrophone housing; and Experimental study of a thick axisymmetric turbulent boundary layer.</p>			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT		21. ABSTRACT SECURITY CLASSIFICATION	
<input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS		Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL		22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
Patrick Leehey		(617)-253-4337	

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted  
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

U.S. Government Printing Office: 1985-507-047

88 1 14 10

Report Number 87144-2

# BODIES IN UNSTEADY FLOW

Patrick Leehey  
Acoustics and Vibration Laboratory  
Massachusetts Institute of Technology  
Cambridge, MA 02139

30 December 1987

Final Report

Prepared for

Office of Naval Research  
Code 1125 A 0  
800 North Quincy St.  
Arlington, VA 22217

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



## Introduction

This is the final technical report of work done under ONR contract N00014-78-C-0696, MIT OSP 87144 and 96570. The work was begun on September 1, 1978 and completed on August 31, 1985. The work accomplished is summarized in four task areas below. Publications, technical reports and theses completed under this task are indexed at the end of this report. They are referenced by author, name and date in the body of the report.

## Vortex Shedding from a Cylinder

A cylindrical floating element force transducer was developed to measure the unsteady forces associated with vortex shedding from a cylinder in a cross flow. The transducer contained an integral accelerometer which served two purposes. Its output was used to compensate for the acceleration sensitivity of the floating element portion of the transducer. It also permitted simultaneous measurement of local force and cylinder motion.

This transducer was used in the MIT Acoustics and Vibration Laboratory's Low Noise Low Turbulence Wind Tunnel to measure fluctuating forces on a cylinder undergoing in cross flow free vibration, Moeller and Leehey [1982-A].

This type of force transducer was next used in the MIT Marine Hydrodynamics Laboratory's Closed Circuit Water Tunnel to determine the forces associated with forced oscillation of cylinders in cross flow. The domain in frequency-displacement space for which the vortex shedding locks into the frequency of cylinder oscillation was determined, Moeller and Leehey [1982-B]. Extensions of this work form the basis of the doctoral dissertation of Moeller [1982]. Measurements were reported by Moeller and Leehey [1984] for both free and forced oscillations of cylinders in cross flow in the water tunnel. The hysteretic behavior of free oscillation of the cylinders was determined at the edges of lock-in boundaries in amplitude and frequency. By forming the product of force and acceleration, power flow from the fluid to the cylinder was measured. A particularly significant observation was made that there was negative power flow in a certain range for forced oscillation, i.e. that power actually flowed from the cylinder to the fluid. This is considered particularly significant as such a phenomenon could not occur under free oscillation.

### Development of a Floating Element Gauge for Measuring Shear Stress

A floating element gauge was developed for measuring shear stress at the wall under a turbulent boundary layer (TBL). This gauge was developed and tested in the Acoustics and Vibration Laboratory's Wind Tunnel, Petri [1984]. The transducer was designed along the principles developed for the cylindrical force gauge discussed above. The active face of the floating element was a square 4mm on a side. The transducer was found to determine the mean wall shear stress accurately in comparison with other methods of shear stress measurement. The measurement of unsteady wall shear stress however, was severely limited by a mechanical resonance in the transducer at 63 Hz. The most significant feature of this development was the extremely small size of the floating element and the fact that the transducer was successfully used as a passive device. It was unnecessary to employ an active force balance principle to keep the floating element centered.

### Axisymmetric Towed Hydrophone Housing

A long towed sonar array has difficulty making starboard/port target discrimination without the ship turning to a new course, a time consuming maneuver. It was considered that it might be feasible to augment the towed array with a pair or more of individual towed bodies each containing a single hydrophone. These could be streamed from the downhaul cable of the towed array, to starboard and port of the main array, and thus provide the desired discrimination. We developed a towed axisymmetric body housing a hydrophone provided by the Naval Underwater Systems Center, New London. We tested this body in the MIT Close Circuit Water Tunnel. The body was first made stable by providing a torsional spring in the towing connection. Self-noise measurements of the body were carried out for towing speeds up to 16 knots over the frequency range from 0.1 - 1.0 kHz. An air chamber was necessary within the body to provide for neutral buoyancy. This chamber permitted discrimination against the background noise of the facility. The pressure-release nature of the chamber however weakened the response of the hydrophone to target signals.

A systems analysis was carried out which showed that a modest change in the hydrophone air-chamber location, involving some lengthening of the test body, would provide desired port/starboard signal discrimination for an adequate detection range at operational speeds, Kim [1984].

## Experimental Study of a Thick Axisymmetric Turbulent Boundary Layer (TBL)

A long towed sonar array creates its own boundary layer which becomes many times thicker than the diameter of the array itself. In order to study the properties of this unusual boundary layer, very long cylinders were stretched the length of Low Turbulence, Low Noise Wind Tunnel and fluctuating velocity components of the boundary layer were measured using hot wires. The first task was to determine a universal law for the mean velocity profile in the flow about the cylinder. It is then possible to predict the boundary layer growth and drag characteristics of the cylinder. We found that a mixed scaling was necessary using the viscous radial coordinate from the cylinder wall and the ratio of local boundary layer thickness to the radius of the cylinder. A logarithmic region was determined. However this logarithmic region relates to a wake-like behavior of the boundary layer rather than to the overlap region associated with the convention planar boundary layer, Lueptow, Leehey, and Stellingner [1985]. This logarithmic law evolved from the assumption of a constant eddy viscosity typical of a wake. The validity of this assumption was justified by measurements of the eddy viscosity, Lupetow and Leehey [1986]. Extensive measurements of velocity dynamics were then carried out, Lueptow and Haritonides [1987]. Variable interval time averaging (VITA) and uv-quadrant techniques were used to detect the burst cycle near the wall. Flow visualization was used to observe the cross-flow eddy structures in the boundary layer of the cylinder moving through a tank of quiescent water. One of the most significant features of this investigation was the observation that large scale structures moved from the outer region on one side of the cylinder to the outer region of the opposite side of the cylinder. The behavior is, of course, impossible in a planar boundary layer. It is considered to be perhaps the most significant feature distinguishing the large axisymmetric boundary layer from the planar boundary layer.

## Concluding Remark

Three Ph. D. dissertations and one M.Sc. thesis were completed in the course of this task.

## References

KIM, J.S., 1984. "feasibility Study of a Small towed Sonar Array Element," MIT Ph. D. Dissertation.

LUEPTOW, R., and HARITONIDIS, J.H., 1987. "The Structure of the Turbulent Boundary Layer on a Cylinder in Axial Flow," Phys. Fluids, 30 (10), 2993-3005.

LUEPTOW, R., and LEEHEY, P., 1986. "The Eddy Viscosity in a Turbulent Boundary Layer on a Cylinder," Phys. Fluids, 29 (12), 4232-4233,

LUEPTOW, R., LEEHEY, P., and STELLINGER, T., 1985. "The Thick, Turbulent Boundary Layer on a Cylinder: Mean and Fluctuating Velocities," Phys. Fluids 28 (12), 3495-3505.

LUEPTOW, R., 1986. "The Turbulent Boundary Layer on a Cylinder in Axial Flow," MIT Ph. D. Dissertation.

MOELLER, M.J., 1978. "Measurement of Unsteady Forces on a Circular Cylinder in Cross Flow at Subcritical Reynolds Numbers," MIT Ph. D. Dissertation.

MOELLER, M.J., and LEEHEY, P., 1982. "Measurement of Fluctuating Forces on a Cylinder in a Cross Flow," Proceeding of 28th International Instrumentation Symposium, Instrument Society of America, 465-487.

MOELLER, M.J., and LEEHEY, P., 1983. "Measurement of Fluctuating Forces on an Oscillating Cylinder in a Cross Flow," Proceedings of the Third International Conference on the Behavior of Offshore Structures, MIT, Hemisphere Publ. Corp. (eds. C. Chyssostomides and J.J. Connor), 681-689.

MOELLER, M.J., and LEEHEY, P., 1984. "Unsteady Forces on a Cylinder in Cross Flow at Subcritical Reynolds Numbers," Proceedings of Symposium on Flow-Induced Vibrations, 1, 57-71, ASME Winter Annual Meeting, Dec. 1984, (New Orleans, LA).

PETRI, S., 1984. "Development of a Floating Element Wall Shear Transducer," MIT Acoustics and Vibration Laboratory Report No. 87144-1.



END  
DATE  
FILMED  
DTIC  
4/88